U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

4.5.1 CONTROL ROD DRIVE STRUCTURAL MATERIALS

REVIEW RESPONSIBILITIES

Primary - Materials Engineering Branch (MTEB)

Secondary - None

I. AREAS OF REVIEW

General Design Criterion 26 requires that one of the reactivity control systems shall use control rods, preferably including a positive means for inserting the rods, and shall be capable of reliably controlling reactivity changes to assure that fuel design limits are not exceeded under conditions of normal operation, including anticipated operational occurrences. The areas listed below relating to materials considerations in the design of the control rod drive mechanism are reviewed. The review areas are similar to those given in Standard Review Plan Section 5.2.3, "Reactor Coolant Pressure Boundary Materials." For the purpose of this SRP section, the control rod system is comprised of the control rod drive mechanism (CRDM) and extends only to the coupling interface with the reactivity control (poison) elements in the reactor vessel; it does not include the electrical and hydraulic systems necessary for actuating the CRDMs.

1. Materials Specifications

   The properties of the materials used in the control rod drive are reviewed from the standpoint of adequate performance throughout the design life of the plant (or component). Materials commonly used include austentic stainless steels (which may be cold worked) chromium-plated stainless steels, martensitic stainless steels, precipitation-hardening stainless steels such as 17-4 PH, and other special-purpose materials such as cobalt-base alloys (Stellites), Inconel-750, Colmonoy-6, and Graphitar-14.

2. Austentic Stainless Steel Components

   Areas of review for austenitic stainless steel components are similar to the applicable subsections of SRP Section 5.2.3 covering fabrication and processing of austenitic stainless steels.

The use of sensitized stainless steels should be controlled to prevent stress-corrosion cracking of the material during operation of the plant. Welding procedures should be controlled to reduce the probability of sensitization and microfissure formation. Cold-worked stainless steels should not have high yield stress, to reduce the probability of stress-corrosion cracking during operation of the plant.

3. Other Materials

Special requirements for the other materials include tempering and aging temperatures for martensitic and precipitation-hardening stainless steels to prevent their deterioration by stress corrosion during operation of the plant. The compatibility of these materials with the reactor coolant is reviewed to assure that they will continue to perform satisfactorily throughout the life of the component.

Metallic and non-metallic materials used in the control rod drive mechanism and not included in Appendix I to Section III of the ASME B&PV Code are identified.

4. Cleaning and Cleanliness Control

Proper care should be taken in handling the materials and parts of the control rod drive mechanism during fabrication, shipping, and onsite storage to assure that all cleaning solutions, processing compounds, degreasing agents, and other foreign materials are completely removed, and that all parts are dried and properly protected following any flushing treatment with water.

In addition, MTEB will coordinate other branches' evaluations that interface with the overall review of the system as follows: the Mechanical Engineering Branch (MEB) reviews the mechanical aspects of the control rod system other than the reactivity control elements as part of its primary responsibility for SRP Section 3.9.4. The Core Performance Branch (CPB) reviews the mechanical design, thermal performance, and chemical compatibility of the reactivity control elements as part of its primary responsibility for SRP Section 4.2.

For those areas of review identified above as being reviewed as part of the primary review responsibility of other branches, the acceptance criteria necessary for the review and their methods of application are contained in the referenced SRP section of the corresponding primary branch.

II. ACCEPTANCE CRITERIA

MTEB acceptance criteria are based on meeting the relevant requirements of the following regulations:

a. General Design Criterion 1 as it relates to structures, systems, and components important to safety being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed.

b. General Design Criterion 14 as it relates to the reactor coolant pressure boundary being designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture.

c. General Design Criterion 26 as it relates to the control rods being capable of reliably controlling reactivity changes so that specified acceptable fuel design limits are not exceeded.

d. Section 50.55a, of Title 10 of the Code of Federal Regulations, Part 50 as it relates to structures, systems, and components shall be designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed.

Specific acceptance criteria necessary to meet the relevant requirements of GDC 1, 14, and 26 and Section 50.55a of 10 CFR Part 50 are as follows:

1. Materials Specifications

The properties of the materials selected for the control rod drive mechanism must be equivalent to those given in Appendix I to Section III of the ASME Boiler and Pressure Vessel Code (hereinafter "the Code"), or Parts A and B of Section II of the Code or are included in Regulatory Guide 1.85, "Code Case Acceptability ASME Section III Materials," except that cold-worked austenitic stainless steels shall have a 0.2% offset yield strength no greater than 90,000 psi, to reduce the probability of stress corrosion cracking occurring in these systems. Regulatory Guide 1.85, "Code Case Acceptability ASME Section III Materials," describes the acceptable code cases that may be used in conjunction with the above specifications.

2. Austentic Stainless Steel Components

Acceptance criteria used are similar to SRP Section 5.2.3, subsections II.4.a, b, d, and e.

Regulatory Guide 1.44, "Control of the Use of Sensitized Stainless Steel," describes acceptance methods for preventing integranular corrosion of stainless steel components. Furnace-sensitized material should not be allowed, and methods described in this guide should be followed for cleaning and protecting austenitic stainless steels from contamination during handling, storage, testing, and fabrication, and for determining the degree of sensitization that occurs during welding. Regulatory Guide 1.31, "Control of Ferrite Content in Stainless Steel Weld Metal," describes acceptance criteria for assuring the integrity of welds in stainless steel components of these systems.

3. Other Materials

All materials for use in this system must be selected for their compatibility with the reactor coolant, as described in Articles NB-2160 and NB-3120 of the Code. The tempering temperature of martensitic stainless steels and the aging temperature of precipitation-hardening stainless steels should be specified to provide assurance that these materials will not

deteriorate because of stress corrosion cracking in service. Acceptable heat treatment temperature include aging at 1050° - 1100°F for Type 17-4 PH and 1050°F for Type 410 stainless.

4. Cleaning and Cleaniness Control

Onsite cleaning and cleanliness control should be in accordance with Regulatory Guide 1.37, "Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components of Water-Cooled Nuclear Power Plants," and ANSI N45.2.1-1973, "Cleaning of Fluid Systems and Associated Components During Construction Phase of Nuclear Power Plants." The oxygen content of the water in vented tanks is not required to be controlled. Vented tanks with deionized or demineralized water are a normal source of water for final cleaning or flushing of funished surfaces. Halogenated hydrocarbon cleaning agents should not be used.

III. REVIEW PROCEDURES

The reviewer will select and emphasize material from the procedures described below, as may be appropriate for a particular case. To ascertain that the acceptance criteria given in subsection II of this SRP section are met, the reviewer examines the review areas listed in subsection I of this SRP section for the required information, using the following procedures:

1. Materials Specifications

The reviewer compares the properties of the materials proposed for the control rod system with Appendix I to Section III of the Code, and Parts A, B, and C of Section II of the Code. He verifies that cold-worked austenitic stainless steels used in fabrication of the reactivity control mechanisms are in conformance with subsection II.1, above.

2. Austenitic Stainless Steel Components

Review procedures are similar to those in SRP Section 5.2.3, subsection III.4.a, b, d, and e. The methods of controlling sensitized stainless steel are examined by the reviewer and compared with the positions given in Regulatory Guide 1.44, especially with respect to cleaning and protection from contamination during handling and storage, verification of non-sensitization of the material, and qualification of welding process employed in production using ASTM A-262. If alternative methods of testing the qualification welds for degree of sensitization are proposed by the applicant, the reviewer determines if these are satisfactory, taking into account branch positions taken on previous applications and the degree of equivalence of the alternate methods. The reviewer may ask the applicant to justify the technical basis for any departures for the cited positions. Alternative tests that have been accepted by the branch include the use of ASTM A-708.

The methods of controlling and measuring the amount of delta ferrite in stainless steel weld deposits are examined by the reviewer and compared to the positions in Regulatory Guide 1.31, "Control of Ferrite Content in Stainless Steel Weld Metal," especially with respect to the filler metal acceptance procedures for the determination of delta ferrite content. If

alternative positions are proposed by the applicant, the reviewer determines if these are satisfactory, taking into account branch positions taken on previous applications. The reviewer may ask the applicant to justify the technical basis for any departures from the acceptance criteria stated in subsection II.2 of this SRP section.

3. Other Materials

The reviewer examines the information provided in the applicant's safety analysis report (SAR) on the compatibility of the materials (other than austenitic stainless steels) to be used in contact with the reactor coolant. He determines that the materials are compatible with the service environment so that corrosion or stress corrosion of the component will not occur during the lifetime of the component. Metallic and nonmetallic materials identified in subsection I.3 of this SRP section are reviewed to assure compatibility and that loss of integrity will not occur during the life of the component.

The reviewer determines that the tempering temperatures of all martensitic stainless steels and the aging temperatures of precipitation-hardening stainless steels have been specified and are in accordance with the acceptance criteria in subsection II.3 of this SRP section.

4. Cleaning and Cleaniness Control

The reviewer verifies that onsite cleaning and cleanliness control procedures are satisfactory and in accordance with subsection II.4 of this SRP section.

IV. EVALUATION FINDINGS

When the reviewer has verified that sufficient and acceptable information has been provided in accordance with the requirements of this SRP section, conclusions of the following type are prepared, to be included in the staff's safety evaluation report:

The staff concludes that the control rod drive mechanism structural materials are acceptable and meet the requirements of General Design Criteria 1, 14, and 26 as well as 10 CFR Part 50, Section 50.55a. This conclusion is based on the applicant having demonstrated that the properties of materials selected for the control rod drive mechanism components exposed to the reactor coolant satisfy Appendix I of Section III of the ASME Code, and Parts A, B, and C of Section II of the Code, and conform with the staff position that the yield strength of cold-worked austenitic stainless steel should not exceed 90,000 psi. The applicant has met the guidelines of Regulatory Guide 1.85 by using materials of construction that are approved for use to ASME code cases.

In addition, the controls imposed upon the austenitic stainless steel of the mechanisms conform to the recommendations of Regulatory Guide 1.31, "Control of Ferrite Content in Stainless Steel Weld Metal," and Regulatory Guide 1.44, "Control of the Use of Sensitized

Stainless Steel." All materials selected for application in the control rod drive mechanism component are or will be in conformance with the applicable code case listed in Regulatory Guide 1.85, "Code Case Applicability ASME Section III Materials." Fabrication and heat treatment practices performed in accordance with these recommendations provide added assurance that stress corrosion cracking will not occur during the design life of the component. The compatibility of all materials used in the control rod system in contact with the reactor coolant satisfies the criteria of Articles NB-2160 and NB-3120 of Section III of the Code. Both martensitic and precipitation-hardening stainless steels have been given tempering or aging treatments in accordance with staff positions. Cleaning and cleanliness control are in accordance with ANSI Standard N 45.2.1-1973, "Cleaning of Fluid Systems and Associated Components During Construction Phase of Nuclear Power Plants," and Regulatory Guide 1.37, "Quality Assurance Requirements for Cleaning Fluid Systems and Associated Components of Water-Cooled Nuclear Power Plants."

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides.

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 1, "Quality Standards and Records."

2. 10 CFR Part 50, Appendix A, General Design Criterion 14, "Reactor Coolant Pressure Boundary."

3. 10 CFR Part 50, Appendix A, General Design Criterion 26, "Reactivity Control System Redundancy and Capability."

4. 10 CFR Part 50, Section 50.55a "Codes and Standards."

5. ASME Boiler and Pressure Vessel Code, Section III, Appendix I, and Section II, Parts A, B, and C, American Society of Mechanical Engineers.

6. ASTM A-262, "Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steel Practice A and E," Annual Book of ASTM Standards, American Society for Testing and Materials.

7. ASTM A-708, "Detection of Susceptibility of Intergranular Corrosion in Severely Sensitized Austenitic Stainless Steel."

8. ANSI N 45.2.1-1973, "Cleaning of Fluid Systems and Associated Components During Construction Phase of Nuclear Power Plants," American National Standards Institute.

9. Regulatory Guide 1.31, "Control of Ferrite Content in Stainless Steel Weld Metal."

10. Regulatory Guide 1.37, "Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components of Water-Cooled Nuclear Power Plants."

11. Regulatory Guide 1.44, "Control of the Use of Sensitized Stainless Steel."

12. Regulatory Guide 1.85, "Code Case Acceptability ASME Section III Materials."